P1.4 NPOESS Interface Data Processing Segment Architecture and Software

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1. INTRODUCTION

Modern space-borne remote sensing of weather data was pioneered in the early 1960s by the Department of Defense (DoD) Defense Meteorological Satellite Program (DMSP). Initial launches of DMSP were joined with vehicles from the Department of Commerce (DOC) Polar Orbiting Operational Environmental Satellites (POES).

Figure 1 depicts the evolution of Government remote sensing systems over the last 40 years. Each next generation has increased the resolution and amount of data collected as well as attempting to reduce the latency of data delivery to Operational users.

NPOESS, the National Polar-orbiting Operational Environmental Satellite System is the next generation low-earth orbiting environmental remote sensing platform.

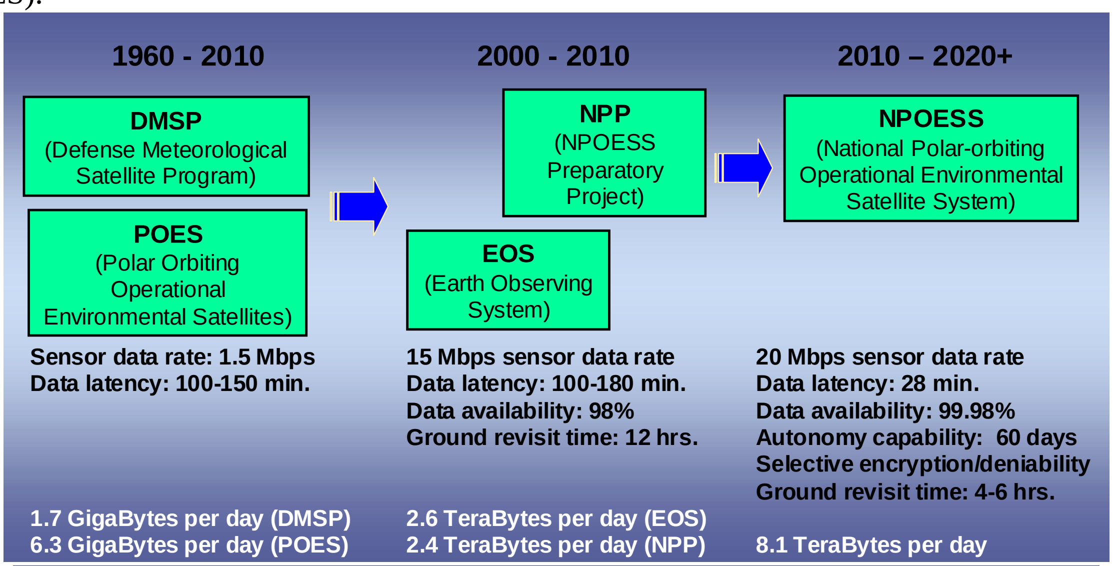

Figure 1- Remote Sensing System Evolution

These pioneer systems flew sensors that were limited in sensed channels and earth coverage. Delivery of sensed data from sensor to end users (latency) was limited due to the polar orbits flown and lack of receiving stations available for download of stored vehicle data.

NPOESS will play a pivotal role in our nation's weather forecasting and environmental awareness for the next two decades. A historic coalition of the nation's military, civil and scientific weather communities has come together for NPOESS, which has resulted in a single system to provide remote sensing of the

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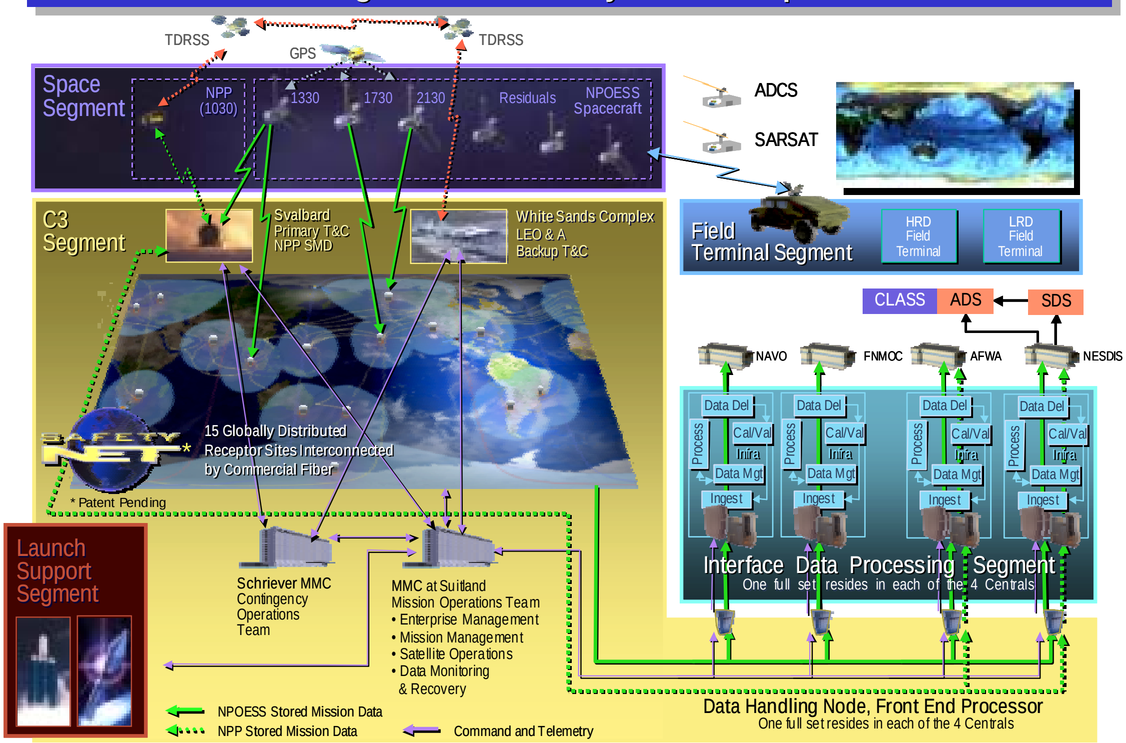
Earth's surface, atmosphere and space environment.

NPOESS provides for remote sensing of the Environment across the spectrum. It allows Centralized Mission Management (with backup) and delivers high quality Environmental products to Military, Civil and Scientific users. This presentation provides an introduction to the System design for NPOESS and provides details on the Interface Data Processing Segment (IDPS), which provides the bulk of product processing.

2. SYSTEM OVERVIEW

Figure 2 is a depiction of the high level Architecture of NPOESS (OV-1). The system is broken into five Segments. The Space Segment (SS) consists of the actual polar orbiting vehicles and their associated sensors and downlinks. The Launch Support Segment (LSS) provides the boosters and support facilities needed for launch and early orbit operations of the vehicles. The Command, Control and Communications Segment (C3S) performs the Mission Management and Control functions for the entire program and receives and routes sensor data and vehicle telemetry from the satellites to the primary mission users. The Interface Data Processing Segment ingests and creates Raw Data Records (RDRs). These gather the various sensor data for a given suite into a time ordered, segmented data structure. Further processing then correlates, calibrates, corrects, and geolocates the RDRs producing Sensor Data Records (SDRs) that are then used in the production of higher level Environmental Data Records (EDRs). All of these products are made available to four government processing facilities: the Air Force Weather Agency (AFWA) in Omaha, NE, Fleet Numerical Meteorology and Oceanography Center (FNMOC) in Monterey, CA, the Naval Oceanographic Office (NAVOCEANO) in Bay Saint Louis, MS, and the National Environmental Satellite, Data, and Information Service

Figure 2- NPOESS System Concept



(NESDIS)/National Center for Environmental Prediction (NCEP) in Suitland, MD. Additionally all products are archived in the NOAA CLASS Long Term Archive (LTA). The LTA makes NPOESS products available to the wider science and general public consumers. A separate Field Terminal Segment (FTS) defines the common processing software and hardware specifications for the building of portable receiving and processing installations for NPOESS data.

One of the keys to NPOESS performance lies in the wide range of Sensor Suites that are being developed and which will be flown on the NPOESS vehicles. Table 1 lists all of the planned sensors and key parameters of their spectral and spatial coverage. Figure 3 lists the producers of each sensor and the heritage sensor used as the basis for the NPOESS evolutionary development.

The NPOESS sensor suites are being designed to deliver 56 primary Environmental Data Records (EDR) to end users. These measurements encompass atmospheric, oceanic, terrestrial, and solar-geophysical parameters. Complementary measurements from multiple instrument suites will improve capabilities for all-weather imaging and sounding.

Development Sensors (NPP)		Sensor Supplier	Heritage/Status
Cross-track Infrared Sounder	CrIS	ITT	CDR August 2003
Visible/Infrared Imager Radiometer Suite	VIIRS	Raytheon SBRS	MODIS / CDR March '02
Advanced Technology Microwave Sounder	ATMS	Northrop Grumman Electronic Systems	AMSU / NPP unit being developed by NASA/GSFC
Conical Scanning Microwave Imager/Sounder	CMIS	Boeing Satellite Systems	SSM/I & TMI / CDR 11/05
Ozone Mapping and Profiler Suite	OMPS	Ball ATC	CDR March '03
Global Positioning System Occultation Sensor	GPSOS	Saab Ericsson (Sw.)	GRAS METOP / CDR June '03
Leverage Sensors			
Radar Altimeter	ALT	Alcatel (Fr.)	JASON & Topex-Poseidon
Earth Radiation Budget Suite	ERBS	NGST	CERES & ERBE
Total Solar Irradiance Sensor	TSIS	CU LASP	TIM & SIM / SORCE Jan '03
Other Sensors			
Space Environment Sensor Suite	SESS	Ball - Various	DMSP, POES, GOES
Advanced Data Collection System	ADCS	CNES (Fr.), NGST	GFE sensor, NGST antenna / POES
Search and Rescue Satellite Aided Tracking	SARSAT	CNES (Fr.), DND (Can.), NGST	GFE sensor, NGST antenna / POES
Aerosol Polarimetry Sensor	APS	Raytheon SBRS	NPOESS procurement delayed due to Replan and NASA GLORY Mission
Survivability Sensor	SS	NGST, Sandia	SSF DMSP

Figure 3 - NPOESS Sensor Listing

Table 1 – NPOESS Sensors and Key Parmaeters

Sensor	Key Parameters
Visible/Infrared Imager Radiometer Suite (VIIRS)	• 0.4 km imaging and 0.8 km radiometer resolution • 22 spectral bands covering 0.4 to 12.5 mm • Automatic dual VNIR and triple DNB gains • Spectrally and radiometrically calibrated • EDR-dependent swath widths of 1700, 2000, 3000 km
Cross-track Infrared Sounder (CrIS)	• 158 SWIR (3.92 to 4.64 µm) channels • 432 MWIR (5.71 to 8.26 µm) channels • 711 LWIR (9.14 to 15.38 µm) channels

	• 3x3 detector array with 15 km ground center-to-center • 2200 km swath width
Conical Scanning Microwave Imager/Sounder (CMIS)	• 2.2 m antenna • RF imaging at 6, 10, 18, 36, 90, and 166 GHz • Profiling at 23, 50 to 60, 183 GHz • Polarimetry at 10, 18, 36 GHz • 1700 km swath width
Advanced Technology Microwave Sounder (ATMS)	• CrIS companion cross track scan • Profiling at 23, 50 to 57, 183 GHz • Surface measurements at 31.4, 88, 165 GHz • 1.1, 3.3, and 5.2 deg (SDRs resampled) • 2300 km swath width
•Ozone Mapping and Profiler Suite (OMPS)	• Total ozone column 300 to 380 nm with 1.0 nm resolution • Nadir ozone profile 250 to 310 nm with 1.0 nm resolution • Limb ozone profile 290 to 1000 nm with 2.4 to 54 nm resolution • Swath width of 2800 km for total column
•Global Positioning System Occultation Sensor (GPSOS)	• RF receiver/processor of GPS signals at 1575.42 and 1227.60 MHz • Velocity, anti-velocity and nadir views
•Radar Altimeter (ALT)	• Measures range to ocean surface with a radar at 13.5 GHz • Corrects for ionosphere with 5.3 GHz radar • Corrects for atmosphere with CMIS water vapor measurements • Precise orbit determination with GPS
Earth's Radiation Budget Suite (ERBS)	• Three spectral channels • Total radiation measurement 0.3 to 50 μm • Shortwave Vis and IR measurement 0.3 to 5 μm • Longwave IR measurement 8 to 12 μm

Total Solar Irradiance Sensor (TSIS)	• Two sensors for total irradiance (TIM) and spectral irradiance (SIM)
	  • TIM measures total solar irradiance
	  • SIM measures spectral irradiance 200 to 2000 nm
	• Pointing platform and sensor suite to be provided by CU LASP

Space Environment Sensor Suite (SESS)	• Sensor suite collecting data on particles, fields, aurora, and ionosphere • Suite includes a UV disk imager (BATC), EUV limb imager (BATC), charged particle detectors (Amptek/U. of Chicago), thermal plasma sensors (UTD), a magnetometer (MEDA), and a coherent beacon sensor (AIL)
Advanced Data Collection System (ADCS)	• ADCS supports global environmental applications
•Search and Rescue Satellite-Aided Tracking (SARSAT)	• SARSAT collects distress beacon signals
•Aerosol Polarimetry Sensor (APS)	• Aerosol characterizations of size, single scattering albedo, aerosol refractive index, aerosol phase function • Multispectral (broad, 0.4 to 2.25 μm) • Multiangular (175 angles) • Polarization (all states)

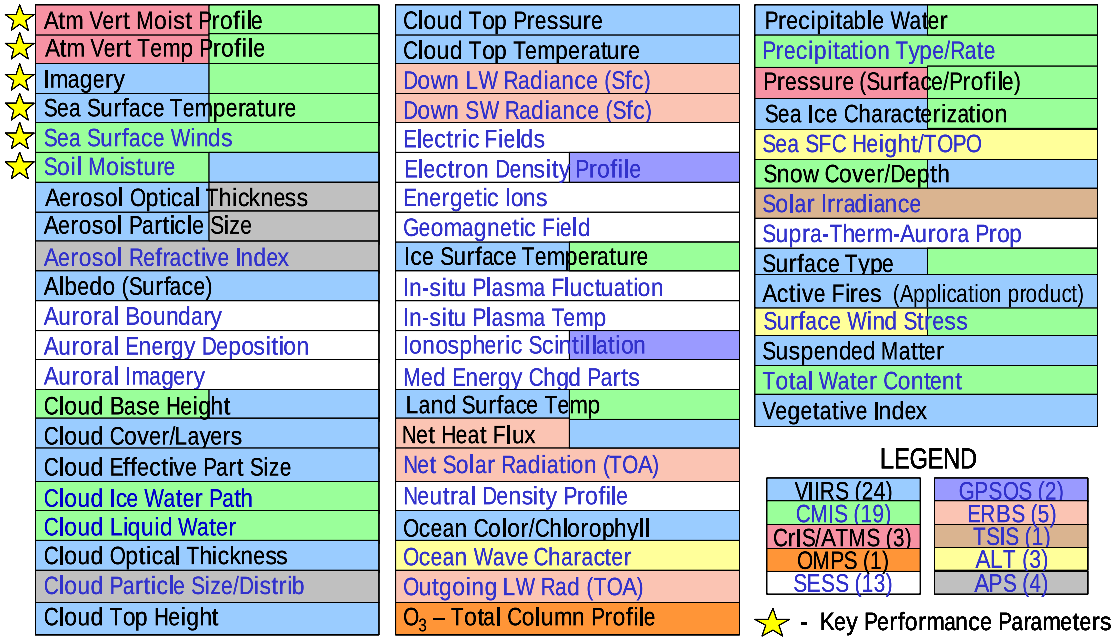


Figure 4 - NPOESS EDR to Sensor Mapping

Figure 4 lists the primary EDRs produced by the IDPS. The sensor suites that contribute to(or in some case provide duplicate) products are keyed via color. There are six EDRs which NPOESS designates as Key Performance Parameters (KPPs). If these EDRs cannot be produced by the orbital constellation due to sensor failure or degradation, NPOESS is required to advance a planned vehicle launch to restore these capabilities.

The NPOESS sensor suites on the NPOESS vehicles produce data at a near constant 20 MB/sec rate. **This is an increase over DMSP of almost 14:1**. The total xDR (RDR, SDR and EDR) products produced by an instance of IDPS per day have a volume **increase over DMSP of 1000:1**

In addition to handling these increased rates, latency requirements (defined as time from sensing of phenomena to production and delivering of products) **decreases by a factor of 4.** A graphical representation of the latency requirements that are imposed on NPOESS and projected actual performance is contained in Figure 5.

Since latency is measured from the sensor all the way through the SS, C3S, and on to IDPS for processing and delay, each NPOESS segment provides functionality to speed data collection and movement over current systems. Details of how this is accomplished will be provided in the following sections that contain more information on each Segment.

3. SEGMENT DETAILS

NPOESS is being procured and managed by a joint Integrated Program Office (IPO) that is staffed by Air Force, National Oceanic and Atmospheric Administration (NOAA) and National Aeronautics and Space Administration (NASA) personnel. A high level schedule for the NPOESS development is provided in Figure 6.

3.1. Space Segment

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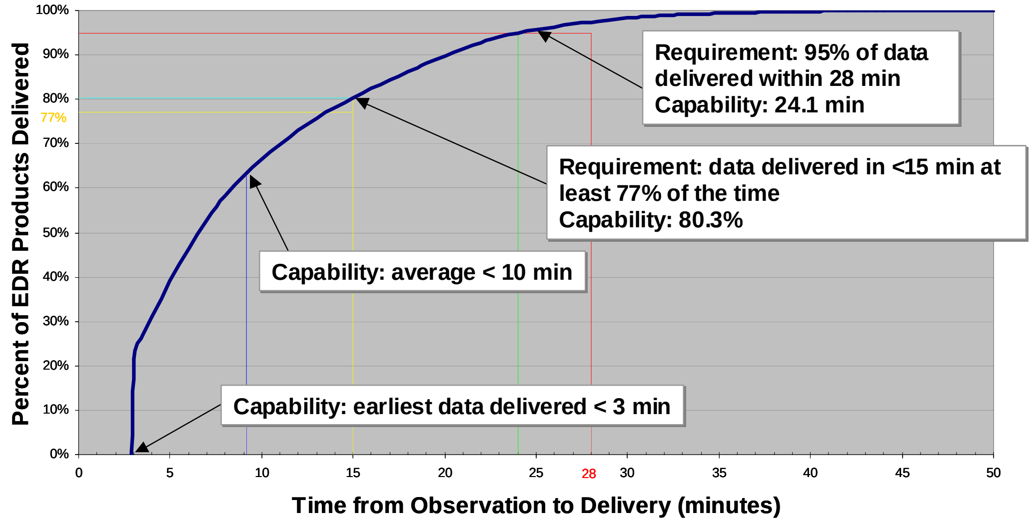


Figure 5 - NPOESS EDR Latency

The SS consists of the satellites and their ground support equipment. The satellites collect global multi-spectral data on clouds and other meteorological, oceanographic, climatological, and solar-geophysical parameters necessary to produce System required products. The NPOESS satellites also carry the ADCS and the SARSAT payloads to support their respective missions. The satellites store and downlink all data to ground stations, and provide a continuous flow of mission data through globally located RF receptors within view of the satellite.

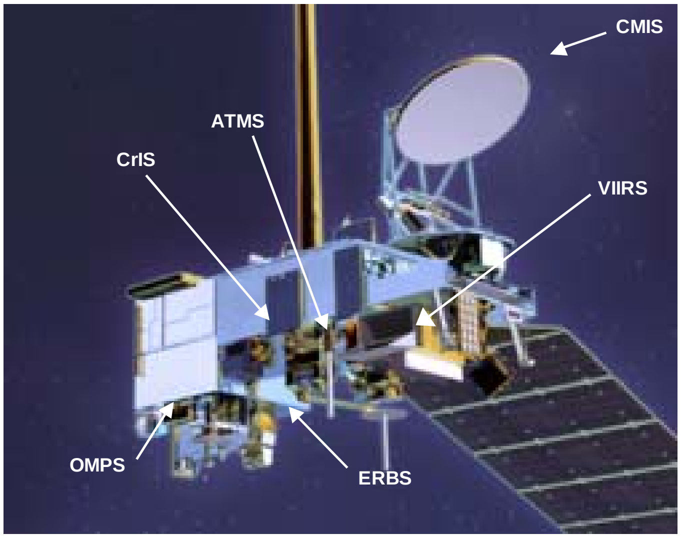
Satellites with specific instrument configurations (see Figure 7) will be placed within these orbits with local time equator crossings. Orbit local crossing times and SS configurations are selected to meet System performance requirements. Each satellite flies in a different circular sun-synchronous orbital plane that always crosses the equator at the same local time. This facilitates collection of satellite data, because images and other measurements are taken at the same latitude at the same local mean solar time (LMST) (same sun angle) each day. These orbits are described by their LTAN crossings of 1330, 1730, and 2130 and are sometimes referred to as the afternoon or PM, morning or AM, and mid-morning satellites, respectively. Figure 8 details the sensor manifest for each of the vehicles in the NPOESS constellation.

3.2. Command, Control and Communications Segment

The C3S provides all functions required for day-to-day state-of-health monitoring and commanding of the NPOESS spacecraft and sensors, and supports delivery of

2002	**A&O Contract Award**
2003	**NPP Delta Critical Design Review**
2005	**NPOESS ΔPreliminary Design Review**
2006	**NPOESS Critical Design Review** **NPP Ground Readiness**
2006	**NPP Launch**
2009	**NPOESS Ground Readiness**
2009	**NPOESS C1 Launch**
2011	**NPOESS C2 Launch** **Field Terminal Segment Readiness** **Initial Operational Capability**
2013	**NPOESS C3 Launch**
2015	**NPOESS C4 Launch**
2017	**NPOESS C5 Launch**
2019	**End of Program**

Figure 6 - NPOESS Program Schedule



NPOESS 1330 Configuration

Figure 7- NPOESS Satellite

meteorological data products to the Users. The C3S also provides system wide data communications with external systems and inter-segment communications between the NPOESS segments. A top-level view of the functional architecture of the C3S is shown in Figure 9.

A key to reducing data latency in the NPOESS system is provided by C3S. By their very nature, Polar Orbiting vehicles orbit over continuously different locations on the Earth (unlike their geo-synchronous brothers). This makes dumping of Stored Mission Data (SMD) from the vehicle problematical, since a terrestrial ground station capable of seeing the vehicle on each (and every!) orbit can only be located near the North or South poles. This limits data transfer to once an orbit and in the case of DMSP, POES and NPOESS implies almost a 100 minute latency for SMD before it can even reach the ground.

The NPOESS C3S answers this problem by implementing a global, distributed set of 15 low cost RF, Receive Only Receptors which are capable of receiving data from the NPOESS vehicles in almost real time. These SafetyNet® receptors are strategically located around the globe at existing fiber communication access points. Planned sites are depicted in Figure 10.

The expected latencies for data collected over specific geographic areas by the NPOESS collection and returned for processing by C3S from SafetyNet® is depicted in Figure 11. Notice that the majority of the global has latencies in the under 10 minute range.

3.3. Interface Data Processing Segment

The IDPS segment combines software and hardware flexibility, expandability, and robustness to meet stringent performance requirements levied by the NPOESS system level requirements.

Sensor application packets are passed to IDPS. The data stream is broken into granules, which are a subsectioning of the data stream into manageable time intervals. The granules of data can be processed in parallel by IDPS thus ensuring processing of high quality products within latency timelines

Fault tolerant hardware and software suites are deployed at each of the four Centrals.

	1330	1730	2130
VIIRS	X	X	X
CMIS	X	X	X
CrIS	X	←	X
ATMS	X	←	X
SESS	X		
GPSOS	X		
OMPS	X		
ADCS	X	X	
SARSAT	X	X	X
ERBS	X		
SS	X	X	X
ALT		X	
TSIS		X	
APS			X

Figure 8- NPOESS Sensor Flight Manifest

Figure 10 – SafetyNet Receptor System

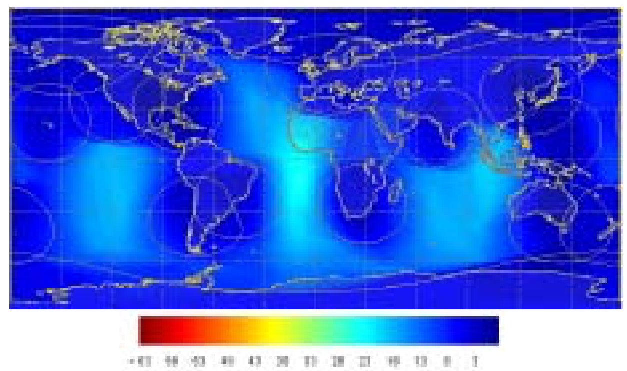


Figure 11 – NPOESS Average Data Latency

Trade studies during the initial NPOESS development showed that distributing the raw data streams to each of the Centrals and doing local (and redundant) processing at each location, limited the communication bandwidth costs over the NPOESS program life. The redundant processing centers ensures maximum data are available to users within operational timelines

Expandable hardware permits addition of new capabilities without impact to existing system

IDPS Operations at each Central require a low level of manning: one 24x7 IDPS operator position (5 heads), one 8x5 Data Quality Engineer position (1 head), one 8x5 IT (SA, DBA, CM) specialist (1 head)

Modular software isolates impacts of changes to basic architecture; provides for rapid, low impact recovery from hardware and software failures. The following sub-sections detail the major software Subsystems that are included in the IDPS.

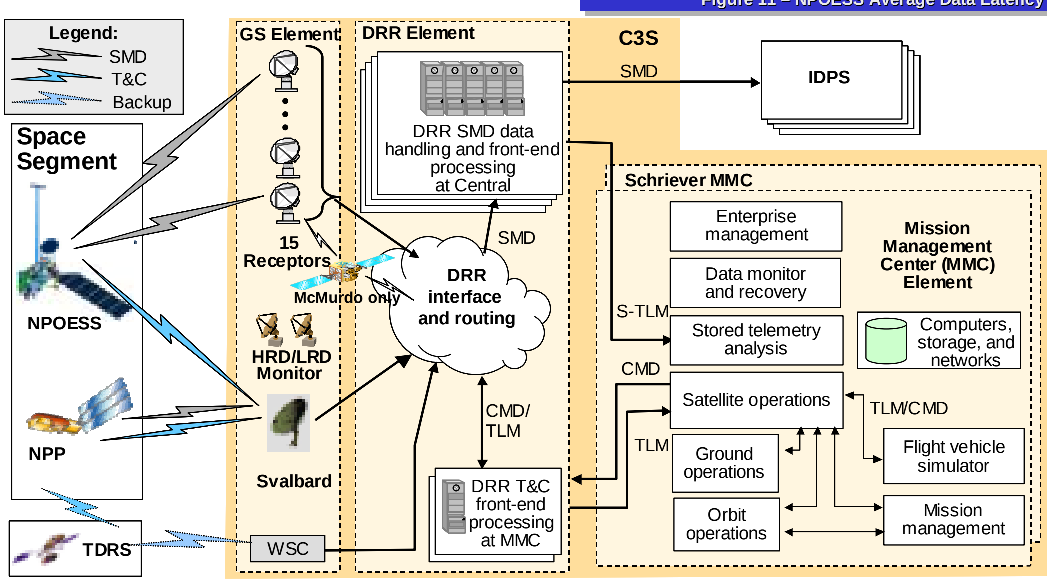


Figure 9 – Command, Control & Communications (C3) Segment

3.3.1. Ingest

The Ingest Subsystem (ING) creates sensor Raw Data Records (RDR) from multiple Sensor Application Packet streams received from C3S. It separates the incoming streams into granules by sensor. Ingest extracts NPOESS Auxiliary data from Stored Mission Data (SMD) and create RDRs or Bus TM and S/C Diary information. It also accepts external Ancillary data sets that are required for EDR processing.

All data ingested is converted into internal, processing optimized formats and place into Data Management.

3.3.2. Processing

The Processing Subsystem (PRO) encapsulates all of the data algorithms that must be executed to turn the RDRs into higher level products.

First processing creates sensor specific SDRs or Temperature Data Records (TDRs) from RDRs. These are corrected, calibrated and Geolocated sensor data.

A complex set of processing chains is then used to produce the required 56 EDRs. Some of these are produced as individual products or one algorithm may yield a group of related EDR products. Predecessor and Successor relationships enforced by Work Flow Manager

Processing also prepares Ancillary data granules to match the geographic coordinates of the produced SDR/TDRs. These accompany the SDR/TDR throughout EDR processing. They are coordinate converted as needed and serve to eliminate duplicate processing by multiple EDRs.

Science code algorithms are wrapped in a modular Input, Processing and Output (I-P-O) model to isolate the processing code from any changes introduced into IDPS. Disk based I/O is replaced with a memory caching access method provided by Data Management.

Throughout all SDR, TDR and EDR production, processing performs real-time data quality checks and can produce real-time reports to Data Quality Monitoring to alert the Data Quality Engineer to suspect data issues.

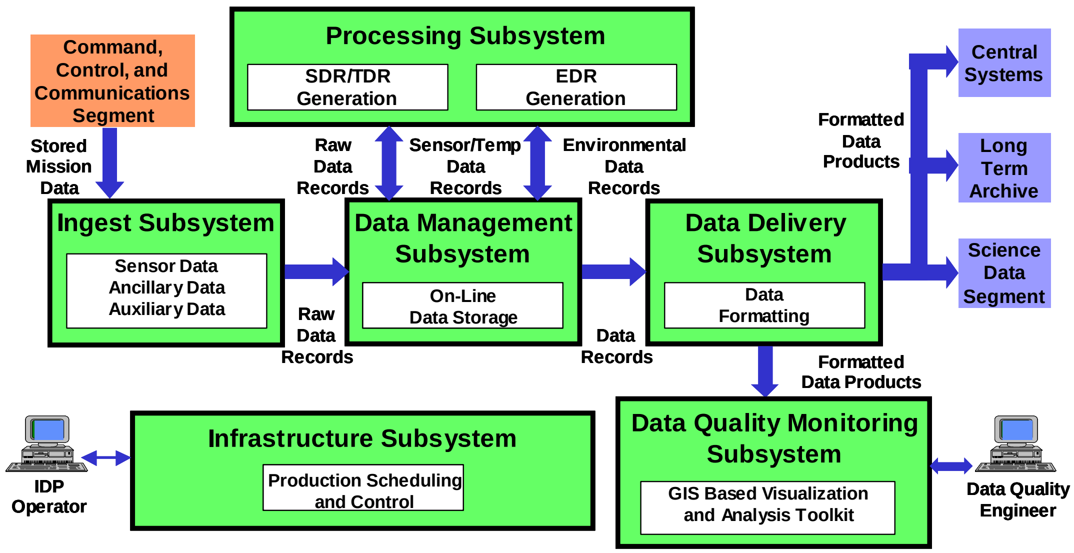


Figure 12 – Interface Data Processing Segment Functional Diagram

3.3.3. Data Management

The Data Management Subsystem (DMS) provides internal short-term (24 hour requirement) storage of all NPOESS data. This storage allows the host Centrals to request data on a delayed basis to match their processing regime. It also allows for “second copy” data processing. If C3S encounters transfer errors from the vehicle to the ground, or through the various ground networks, IDPS will process the “error” data. C3S can retrieve an error free copy of the same data from various points within the system. These sources include various routing points in CONUS, the Ground Receptors themselves and can even extend back to the actual vehicle with a command re-transmit of data stored on-board in the Solid State Recorder (SSR). IDPS can insert the “better” data into DMS and produce any products that had initially be affected by the errors.

DMS stores Inventory metadata as well as Binary Large Objects (BLOBs). The metadata is used by IDPS to access data in the short -term store through metadata based queries.

DMS provides a coherent, multi-LPAR/Node memory cache system. This is used to keep all required data in memory until all processing is complete. It provides for a single copy shareable by multiple processes.

Finally, DMS can archive, backup/restore and eliminate data through aging rules

3.3.4. Data Delivery

The Data Delivery Subsystem (DDS) is the single provider of all data between IDPS and the local Central.

It converts requested products into Hierarchical Data Format5 (HDF5) format with data and metadata aggregation. HDF5 is a self-describing data format with community supplied implementation libraries and is an emerging JTA standard.

DDS accepts delivery requests from the Central user. These requests specify which products are required as well as specifying aggregation parameters (from a single IDPS granule to an entire orbit) delivery schedules and delivery parameters. The Centrals only receive products that they desire, although IDPS produces the entire set for all data received.

Data requests and progress and status are provided both through a GUI and API provided for Central users/applications to request data

3.3.5. Infrastructure

The Infrastructure Subsystem (INF) provides the Workflow management functions for IDPS. It has total control of process startup, monitoring, shutdown and re-start upon error conditions.

It enforces pre-conditions (Predecessor and Successor) relationships in processing chains and provides the main IDPS Operator I/F with the system.

Various INF libraries are included that provide common services to all of the other IDPS Subsystems. These include logging, debug, Enterprise management, Data accountability, and time and unit conversions.

3.3.6. Data Quality Monitoring

The Data Quality Monitoring Subsystem (DQM) provides the Data Quality Engineer automated and ad-hoc processing in support of Data Quality Notifications from the Processing system. These notifications are based upon thresholds for xDR product values that are supplied by DQM to the Processing subsystem. If any of these thresholds are exceeded during normal process, DQM is able to gather needed information from the IDPS automatically.

The Data Quality Engineer is provided with a tool kit of Geographic Information System based modules that allow the IDPS data to be registered to a geographic grid and analyzed, viewed and correlated with available “truth” data to isolate data anomalies.